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Preprint · January 2020

DOI: 10.13140/RG.2.2.27065.80486

Annals of Plant and Soil Research 22(4): 324-335(2020)

Nanofertilizers for enhancing nutrient use efficiency, crop productivity and economic returns in winter season crops of Rajasthan

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Received: August, 2020; Revised accepted: September, 2020

ABSTRACT

The results of 600 on-farm trials with 8 crops conducted during winter season in different districts of Rajasthan have proved that the quantity of urea being applied by the farmers to supply nitrogen to the crops can be successfully reduced to half. The yields obtained with 50% less nitrogen plus 2 sprays of nano-nitrogen in standing crops gave yields higher than that applied in most of the 8 crops tested in these trials. Apart from this, effect of the Nano-Zn and Nano-Cu was also evaluated. As the deficiencies of these micronutrients were not universal like nitrogen, the significant responses to these nanofertilizers depended on the magnitude of deficiency of specific micronutrients and the nature of the crops.These results clearly establish that with application of nanofertilizers, the nutrient use efficiency can be significantly enhanced as revealed by 50 per cent saving of urea through 2 sprays of Nano N.Nanofertilizers are considered as a novel approach towards saving of nutrients, in particular nitrogen, and protecting the environment.This paper describes the results of 600 on-farm trials conducted on 8 crops grown during winter season of 2019-20.

Keywords: Nanofertilizers, nutrient use efficiency, crop productivity, winter season crops

INTRODUCTION

World agricultural cropping systems are intensively using large amount of fertilizers, pesticides, herbicides to achieve more production per unit area per unit time but using more doses than optimum of these chemicals and fertilizers leads to several problems like environment pollution (soil, water, air pollution), low input use efficiency, decreased quality of food products, increasing problems of pests (weeds, diseases, insects), less income from the production, soil degradation, increasing incidence of multi-nutrient deficiencies in soil and plants, decreasing population of beneficial organisms in the soil and on the whole soil health problems. Despite these problems, there is also challenge to ensure food, nutrition and environment security to feed the growing population of the world in the face of shrinking natural resources and deteriorating soil health. Therefore, in the future, there is need to produce nutritive agricultural produce rich in protein and other essential nutrients required to the human and animal consumption that is why emphasis should be laid on production of high quality food with the required level of nutrients and proteins. Apparently, agriculture in the twenty-first century is facing manifold challenges for producing more food by addressing the problems of rapidly global population, unpredictable climate change, decreasing agricultural productivity, variable labour force, and increased growing urbanization. These problems seem to intensify ferociously by 2050 when the world have to feed the population of over 9 billion. Agriculture as a source of food, feed, fodder and fibre has always been increasingly important in a world of diminishing resources and with an ever-increasing global population (Brennan 2012). There is also demanding need for agriculture to produce more output with less input. To address this scenario, the agriculture dependent countries have to adopt more advanced technologies, labour saving practices, and methods. The use efficiency of nutrients of traditional fertilizers is abysmally low. It has been reported that around 40-70% of nitrogen, 80-90% of phosphorus, and 50-90% of potassium content of applied fertilizers are lost in the environment and could not reach the plant which causes significant economic losses (Trenkel 2010, Solanki *et al.* 2015).

Among most recent technical improvements in the field of agriculture, nanotechnology holds an eminent position in remodelling agriculture and food production to fulfil the demands in an efficient and cost-effective way. Nanotechnology is a promising tool and has the potential to foster a new era of precise farming techniques and therefore, may emerge as a possible solution for these problems. Nanotechnology has the potential to improve global food production and food quality (Sugunan and Dutta 2008). Engineered nanomaterials can alter agronomic traits including plant growth, biomass production; physiological parameters that directly influence yield and quality of produce (Gardea-Torresdey *et al.* 2014. Zheng *et al.* 2005). Nanofertilizers are nutrient carriers of nano dimensions ranging from 30 to 40 nm and capable of holding bountiful of nutrient ions due to their high surface area and release it slowly and steadily that commensurate with crop demand (Subramanian *et al.* 2015) and have a profound influence on crop production (Panwar*et al.* 2012, De Rosa *et al.* 2013). The use of nanofertilizers not only causes increased use efficiency through ultrahigh absorption of the nutrients, increase in photosynthesis caused by expansion in surface area of the leaves (INIC 2009) but also reduces the toxicity generated due to over application in the soil as well as reduces the split application of fertilizers (Naderi and Danesh-Shahraki 2013). Despite the high potential of NPS in enhancing plant growth and development, the information on the effect of nanofertilizers on agronomic traits based on field experiments are almost lacking. This research aims at studying the effect of IFFCO Nano fertilisers (Nano-N, Nano-Zn and Nano-Cu) on crop yield, nutrient use efficiency and economic returns.

MATERIALS AND METHODS

Six hundred on-farm trials were conducted with 8 crops namely wheat (*Triticumaestivum*), barley (*Hordeum vulgare*), maize (*Zea mays*), urdbean (*Vigna mungo*), chickpea (*Cicer arietinum*), mustard (*Brassica juncea*), isabgoal(*Plantago ovata)* and rose (*Rosa damascene*) in different districts of Rajasthan during winter season of 2019-20. The crops were sown in the month of November and December 2019 with 5 treatments (Table 1).The Nanofertilizers namely Nano-N, Nano-Zn and Nano-Cu (Picture 1) had nutrient concentrations of 25000, 5000 and 2000 ppm, respectively. Four ml. of these liquid fertilisers were added in one litre of water and for one acre 500 ml of nanofertilizers were added to 125 litres of water and sprayed as per treatments. The first spray was done 3 week after full germination in each crop and the second spray was made 10-15 days after first spray or 5 weeks after full germination. The fields were kept weed-free as far as practical according to means and will of the farmers. Plant protection measures were adopted as per need of the crop. The crops were harvested at full maturity and the yield data were recorded from the net plot area harvested.

Table 1: Treatment details

T_1	Farmer’s Fertiliser Practice (FFP)
T_2	FFP - 50% N + 2 Spray of Nano Nitrogen
T_3	FFP + 2 Spray of Nano Zinc
T_4	FFP + 2 Spray of Nano Cu
T_5	FFP - 50% N + 1 Spray of Nano N + 1 Spray of Nano Zn + 1 Spray of Nano Cu

Picture 1: IFFCO Nanofertilizers tested in this investigation

RESULTS AND DISCUSSION

Data emanating from 600 on-farm trials with respect to economic yield, the range and mean of responses, additional yield and economic returns recorded over FFP for 8 crops are given in Table 2. The crop-wise results are being described in following paragraphs.

Wheat (*Triticum aestivum*)

Mean effects of nanofertilizers on grain yield of wheat under different treatments, additional yield and economic returns over FFP are summarized in Table 2 and Fig. 1. The lowest and highest grain yields as influenced by different nano- treatments varied between 2250 and 2400 and 6410 and 6875 kg ha^{-1} respectively, the mean yields being in the range of 4330 to 4628 kg ha^{-1}.

Table 2: Effect of nanofertilizers on yield of crops

Crop (Data in parenthesis are number of trials)	Parameters	Farmer Fertilizer Practice (FFP)	FFP -50%N + 2 Spray of Nano -N	FFP + 2 Spray of Nano-Zn	FFP+ 2 Spray of Nano Cu	FFP (-50% N) + 1 Spray of Nano-N+ 1 Spray of Nano-Zn+ 1 Spray of Nano-Cu
Wheat (480)	Lowest yield (kg ha^{-1})	2250	2400	2370	2370	2380
	Highest yield (kg ha^{-1})	6410	6760	6610	6580	6875
	Mean yield (kg ha^{-1})	4330	4580	4490	4475	4628
	Response over FFP (kg ha^{-1})	-	250	160	145	297.5
	Per cent increase over FFP	-	5.77	3.7	3.35	6.87
	Net return over FFP (Rs. ha^{-1})	-	4812.50	3080.00	2791.25	5726.88
Barley (9)	Lowest yield (kg ha^{-1})	3200	3380	3300	3250	3350
	Highest yield (kg ha^{-1})	5260	5620	5730	5790	5900
	Mean yield (kg ha^{-1})	4230	4500	4515	4520	4625
	Response over FFP (kg ha^{-1})	-	270	285	290	395
	Per cent increase over FFP	-	6.38	6.74	6.86	9.34
	Net return over FFP (Rs. ha^{-1})	-	4117.50	4346.25	4422.50	6023.75
Maize (4)	Lowest yield (kg ha^{-1})	4100	4300	4400	4100	4500
	Highest yield (kg ha^{-1})	5500	6000	5700	5550	6000
	Mean yield (kg ha^{-1})	4800	5150	5050	4825	5250
	Response over FFP (kg ha^{-1})	-	350	250	25	450
	Per cent increase over FFP	-	7.29	5.21	0.52	9.38
	Net return over FFP (Rs. ha^{-1})	-	6160	4400	440	7920
Chickpea (27)	Lowest yield (kg ha^{-1})	1437	1566	1498	1466	1677
	Highest yield (kg ha^{-1})	2500	2700	2650	2600	2650
	Mean yield (kg ha^{-1})	1969	2133	2074	2033	2164
	Response over FFP (kg ha^{-1})	-	165	106	65	195
	Per cent increase over FFP	-	8.36	5.36	3.28	9.91
	Net return over FFP (Rs. ha^{-1})	-	8019.38	5143.13	3144.38	9506.25
Urdbean (3)	Lowest yield (kg ha^{-1})	1650	1850	1925	1750	1975
	Highest yield (kg ha^{-1})	1700	1850	2000	1800	2150
	Mean yield (kg ha^{-1})	1675	1850	1963	1775	2063
	Response over FFP (kg ha^{-1})	-	175	288	100	388
	Per cent increase over FFP	-	10.45	17.16	5.97	23.13
	Net return over FFP (Rs. ha^{-1})	-	9975	16387.50	5700	22087.50
Mustard (70)	Lowest yield (kg ha^{-1})	1100	1200	1170	1120	1180
	Highest yield (kg ha^{-1})	4200	4300	4500	4200	4600
	Mean yield (kg ha^{-1})	2650	2750	2835	2660	2890
	Response over FFP (kg ha^{-1})	-	100	185	10	240
	Per cent increase over FFP	-	3.77	6.98	0.38	9.06
	Net return over FFP (Rs. ha^{-1})	-	4425	8186.25	442.50	10620
Isabgol (3)	Lowest yield (kg ha^{-1})	1000	1040	1050	1030	1065
	Highest yield (kg ha^{-1})	1120	1165	1140	1130	1195
	Mean yield (kg ha^{-1})	1060	1102.5	1095	1080	1130
	Response over FFP (kg ha^{-1})	-	42.5	35	20	70
	Per cent increase over FFP	-	4.01	3.3	1.89	6.6
	Net return over FFP (Rs. ha^{-1})	-	4186.25	3447.50	1970	6895
Rose (4)	Lowest yield (kg ha^{-1})	27000	29000	29000	28750	30500
	Highest yield (kg ha^{-1})	30000	32500	32500	33000	35000
	Mean yield (kg ha^{-1})	28500	30750	30750	30875	32750
	Response over FFP (kg ha^{-1})	-	2250	2250	2375	4250
	Per cent increase over FFP	-	7.89	7.89	8.33	14.91
	Net return over FFP (Rs. ha^{-1})	-	67500	67500	71250	127500

The grain yield under T5 (FFP-50% N) + one spray of each of Nano N, Zn, Cu) was the highest (4628 kg ha^{-1}) with additional increase of 297.5 kg ha^{-1} over FFP and per cent increase of 6.87. The economic return over FFP was also highest with T_5 (Rs. 5726.88 ha^{-1}) and second in order was T_2 (FFP-50% N + 2 Spray of Nano N). As compared to FFP, the economic return with T_3 (FFP + 2 Spray of Nano Zn) and T_4 (FFP + 2 Spray of Nano Cu) were Rs. 3080 and 2791 ha^{-1} respectively.

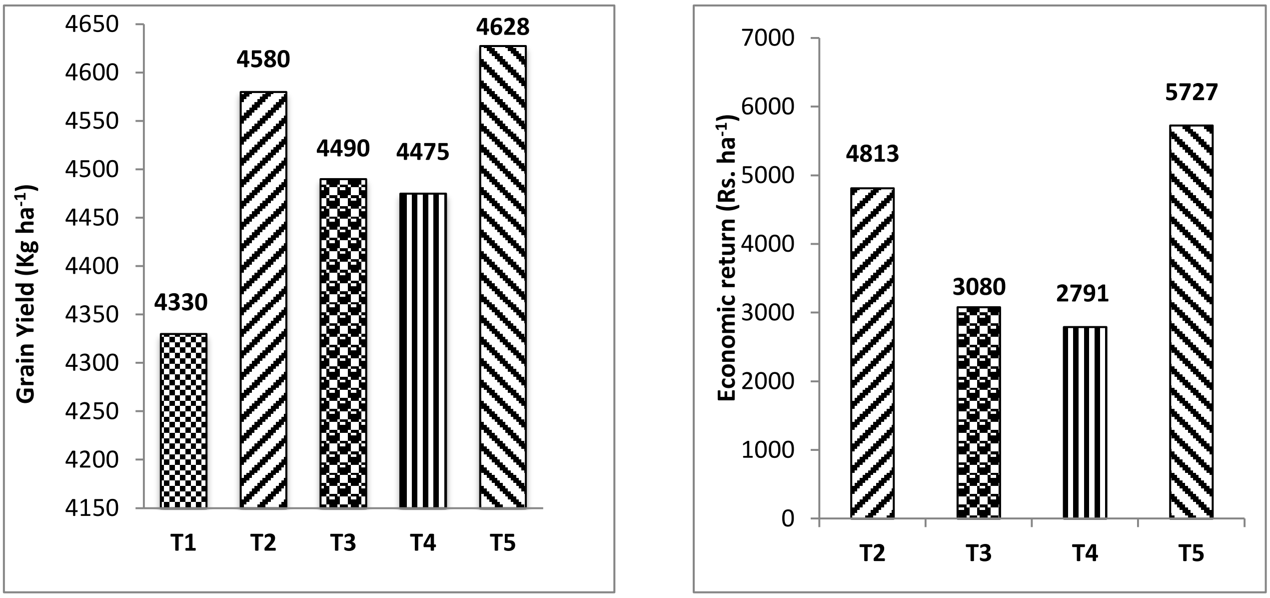


Fig 1: Mean effect of IFFCO Nanofertilizers on grain yield of wheat and economic returns (No. of trials – 480)

Barley (*Hordeum vulgare*)

The lowest yields of barley ranged from 3200 and 3380 kg ha^{-1} while the highest yield varied between 5260 and 5900 kg ha^{-1}under different treatments being highest with T_5 and the lowest with FFP. The mean yields were in the range of 4230 to 4625 kg ha^{-1}. The yield under T_5 was the highest (4625 kg ha^{-1}) with additional yield of 395 kg ha^{-1} over FFP and per cent increase of 9.34. The economic return over FFP was also highest with T_5 (Rs. 6023.75 ha^{-1}) followed by T_4 (Rs. 4422.50), T_3 (FFP + 2 Spray of Nano Zn) (Rs.4346.25) and T_2 (FFP-50% N + 2 Spray of Nano N) (Rs. 4117.50), respectively (Table 2 and Fig. 2).

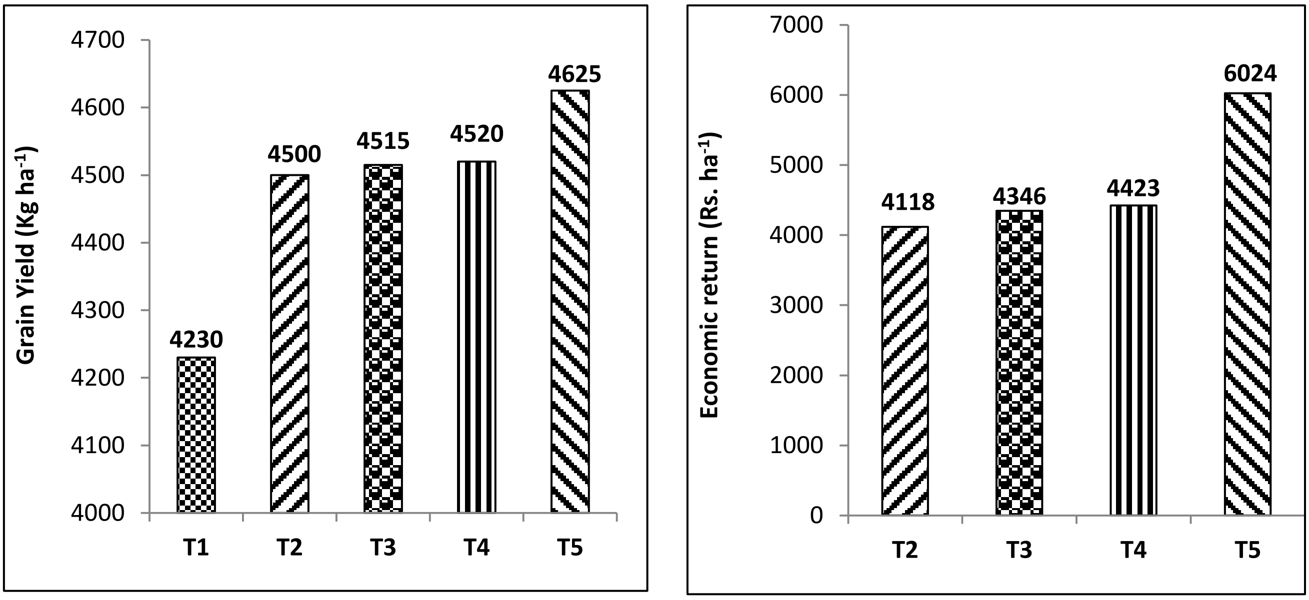


Fig. 2: Mean effect of IFFCO Nanofertilizers on grain yield of Barley and economic returns (No. of trials – 9)

Maize (*Zea mays*)

Data presented in Table 2 and Fig. 3 show that the lowest grain yield of maize as influenced by different treatments ranged from 4100 to 4500 and the highest from 5500 to 6000 kg ha^{-1}. The mean grain yield under different treatments varied between 4800 and 5250 kg ha^{-1} being highest under T_5 and the lowest under FFP with per cent increase of 9.38. The additional yield under T_5 over FFP was 450 kg ha^{-1}. The economic return over FFP was also highest with T_5 (Rs.7920 ha^{-1}) followed by T_2 (Rs.6160 ha^{-1}), T_3 (Rs.4400 ha^{-1}), and T_4 (Rs. 440 ha^{-1}).

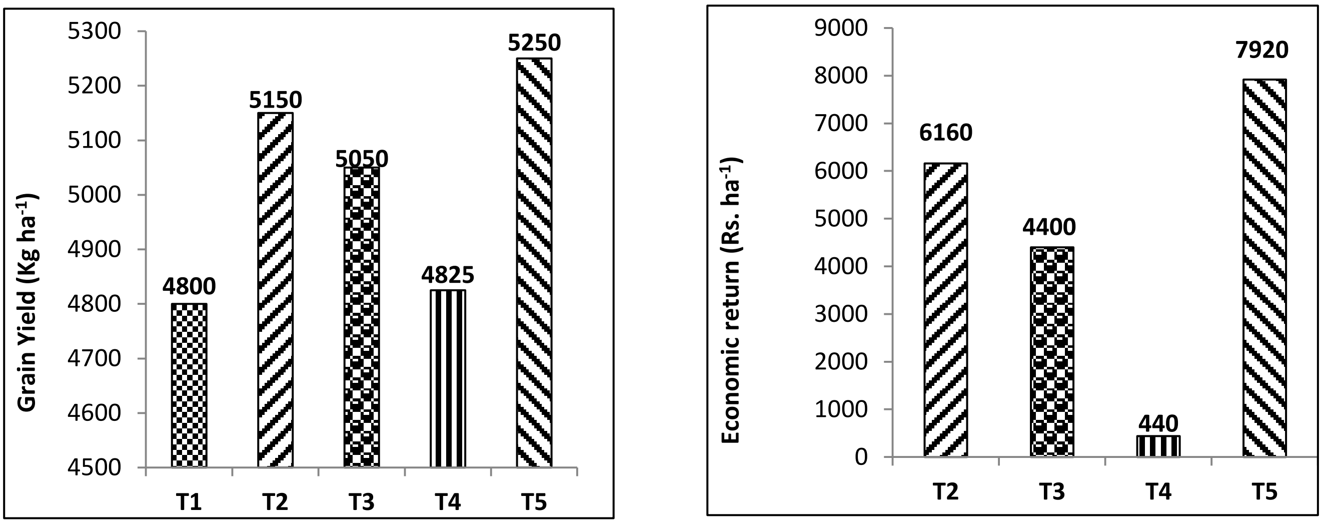


Fig. 3: Mean effect of IFFCO Nanofertilizers on grain yield of maize/ Corn and economic returns (No. of trials–4)

Chickpea (*Cicer arietenum*)

Perusal of the data from the field trials of chickpea presented in Table 2 and Fig.4 shows that the lowest grain yield under different treatments ranged from 1437 to 1677 kg ha^{-1} and the highest from 2500 to 2700 kg ha^{-1}). The grain yield was highest under T5 (2164 kg ha^{-1}) with per cent increase of 9.91and the lowest under FFP (1969 kg ha^{-1}). The next highest yield was with T_2 (FFP-50% N) + 2 Spray of Nano N) (2133 kg ha^{-1} with additional yield of 165 kg ha^{-1} valuing Rs. 8019.38 ha^{-1} over FFP. The highest yield (2164 kg ha^{-1}) with additional yield of 195 kg ha^{-1} and percent increase to the order of 9.01% gave economic return to the tune of Rs. 9506 ha^{-1} over FFP. The economic returns with T_2, T_3 and T_4 were Rs. 8019, 5143, and 3144 respectively over FFP.

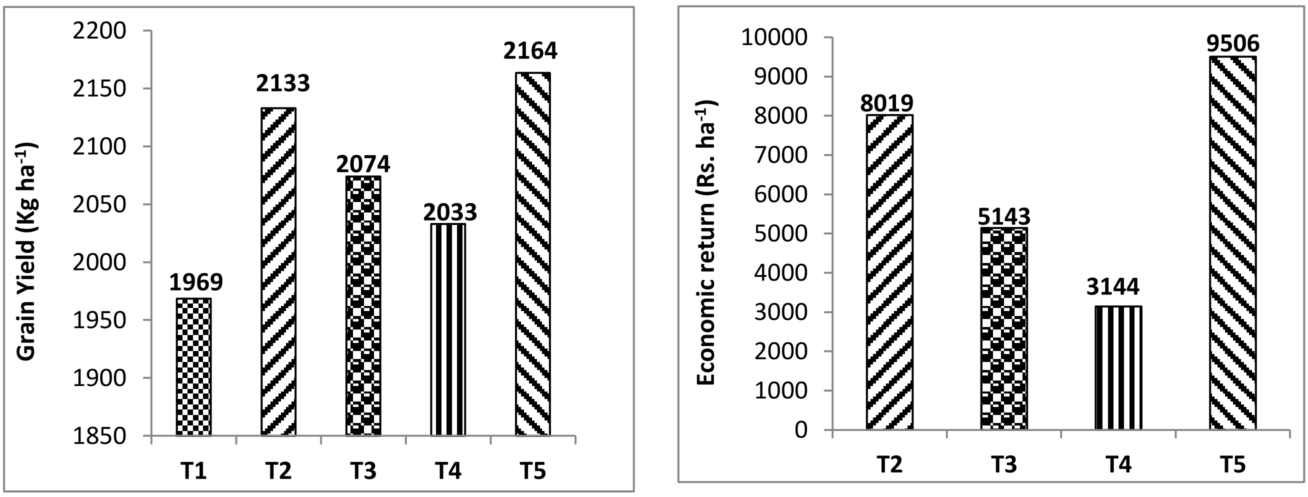


Fig. 4: Mean effect of IFFCO Nanofertilizers on grain yield of Chick Pea/ BangalGram and economic returns (No. of trials–27)

Urdbean (*Vigna mungo)*

Data on grain yield of urdbean and economic returns as influenced by different treatments presented in Table 2 and Fig. 5 show that the lowest grain yield under different treatments ranged from 1650 to 1975 kg ha^{-1} with highest yield from 1700 to 2150 kg ha^{-1}. The mean grain yield ranged from 1675 to 2063 kg ha^{-1} being the highest under T5 (2063 $kg^{-1}ha$) and the lowest under FFP (1675 kg ha^{-1}) with per cent increase of 23.13.The additional grain yield under different treatments over FFP varied between 100 to 388 kg ha^{-1} being highest under T_5 (388 kg ha^{-1}) followed by T_3 (288 kg ha^{-1}), T_2 (175 kg ha^{-1}) and T_4 (100 $kgha^{-1}$). The economic return over FFP was also highest with T_5 (Rs. 22087 ha^{-1}) followed by T_3 (Rs.16387 ha^{-1}), T_2 (Rs.9975 ha^{-1}) and T_4 (Rs. 5700 ha^{-1}).

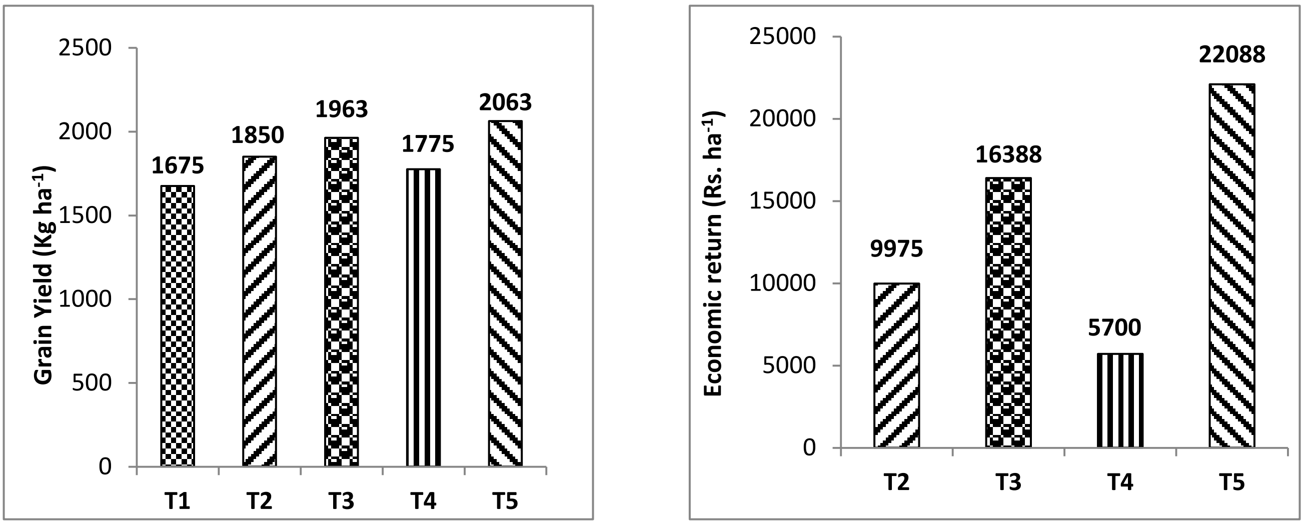


Fig. 5: Mean effect of IFFCO Nano-Fertilizers on grain yield of urdbeanand economic returns (No. of trials–3)

Mustard (*Brassica juncea*)

Data on grain yield, additional grain yield and economic returns of mustard as influenced by different treatments presented in Table 2 and Fig. 6show that the lowest yieldsvaried in a very narrow range from 1100 to 1200 kg/ha and the highest from 4200 to 4600 kg ha^{-1}.

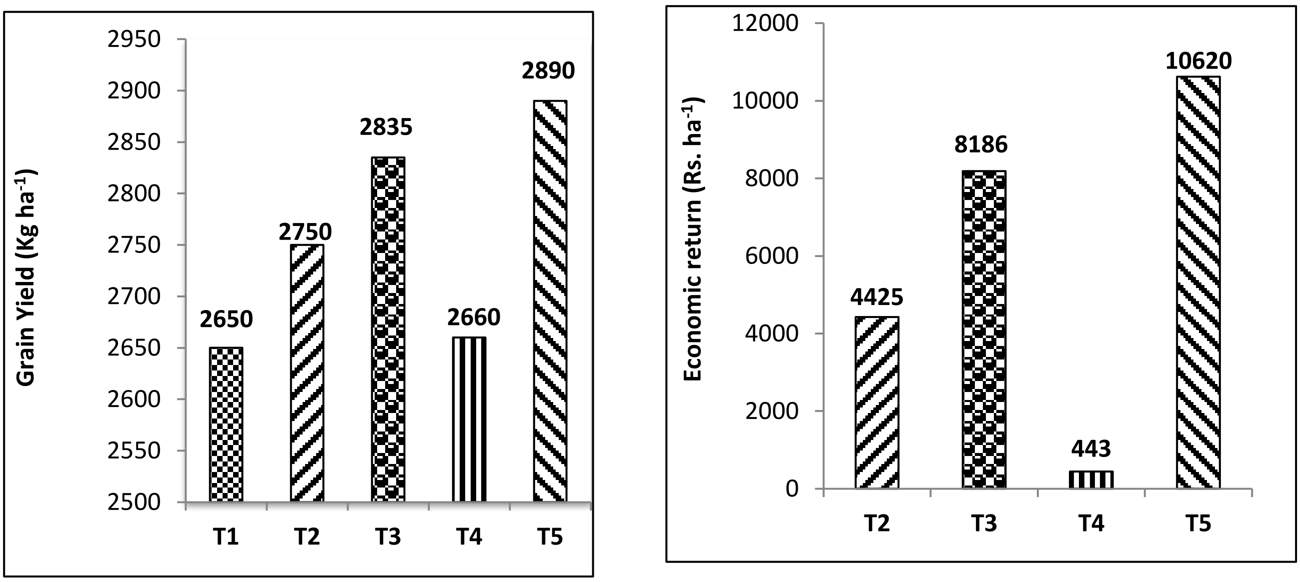
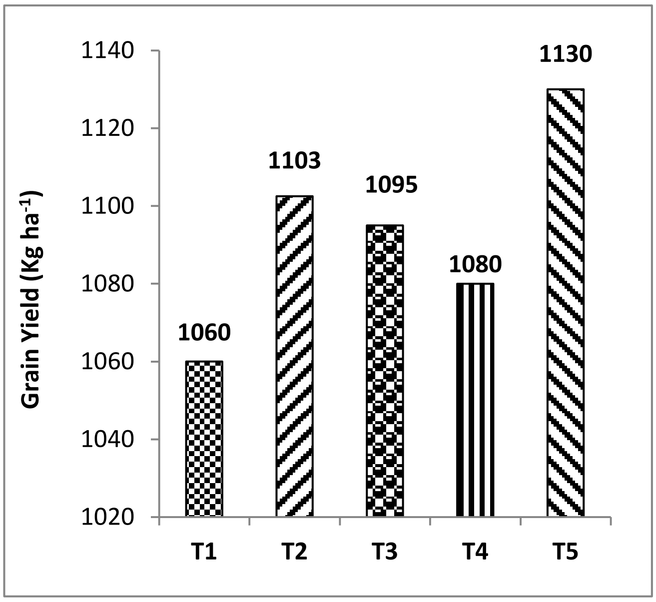


Fig. 6: Mean effect of IFFCO Nanofertilizers on grain yield of mustard and economic returns (No. of trials–70)

The mean grain yield under different treatments varied between 2650 and 2890 kg ha^{-1} being highest under T5 and the lowest under FFP with per cent increase of 9.91. The additional yield under 5 over FFP was 240 kg ha^{-1} followed by T_3 (185 kg ha^{-1}), T_2 (100 kg ha^{-1}) and T_4 (10 kg ha^{-1}). The economic return over FFP was also highest with T_5 (Rs.10620 ha^{-1}) followed by T_3 (Rs.8186 ha^{-1}), T_2 (Rs.4400 ha^{-1}), and T_4 (Rs. 442 ha^{-1}).

Isabgol (*Plantago ovata)*

Effect of nanofertilsers on grain yield, additional grain yield and economic returns over FFP have been presented in Table 2 and Fig. 7**.**The lowest yield of isabgolas influenced by different treatments ranged from 1000 to 1065 kg ha^{-1}, the highest between 1120 and 1195 kg ha^{-1} and the mean yield in the range of 1060 to 1130 kg ha^{-1}. The mean yield was highest under T_5 (1130 kg ha^{-1}) followed by T_2 (1103 kg ha^{-1}), T_3 (1095 kg ha^{-1}) and T_4 (1080 kg ha^{-1}) and T_1 (1060 kg ha^{-1}). The additional yield over FFP followed the same trend being 70, 42, 35 and 20 kg ha^{-1} under T_5, T_2, T_3 and T_4, respectively. The economic return over FFP was also highest with T_5 (Rs.6895 ha^{-1}), followed by T_2 (Rs.4186 ha^{-1}), T_3 (Rs. 3448 ha^{-1}) and T4 (Rs.1970 ha^{-1}).



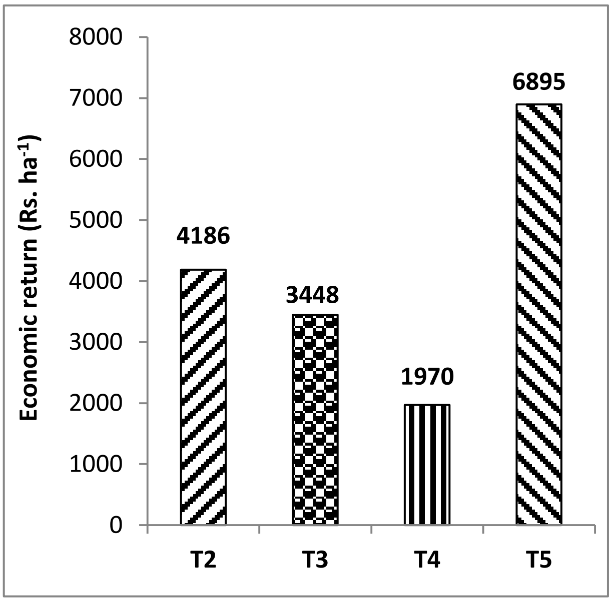


Fig. 7:Mean effect of IFFCO Nanofertilizers on the yield of Isabgol and economic returns (No. of trials – 3)

Rose *(Rosa damascene)*

Perusal of the data from the field trials of roses (Table 2 and Fig.8) showed that the lowest flower yields as influenced by different treatments varied in the range of 27000 to 30500 kg ha^{-1}, the highest between 30000 and 35000 kg ha^{-1} and the mean yield in the range of 28500 to 32750 kg ha^{-1}. The flower yield was highest under T_5 (32750 kg ha^{-1}) with per cent increase of 14.91 and the lowest under FFP (28500 kg ha^{-1}). The next highest yield (30875 kg ha^{-1}) was with T_4 (FFP + 2 Spray of Nano Cu) followed by T_2 and T_3 (30750 kg ha^{-1}) and the lowest under FFP (28500 kg ha^{-1}) with additional yield of 4250 kg ha^{-1} over FFP under T_5, 2375 kg ha^{-1} under T_4 and 2250 kg ha^{-1} under T_2 and T_3 and valuing Rs. 127500 ha^{-1} under T_5, Rs. 71250 under T_4, and Rs. 67500 under T_2 and T_3 over FFP.

Conventional fertilizers offer nutrients in chemical forms that are not fully accessible to plants. Additionally, the inversion of these chemicals to insoluble form in soil is the reason for the very low utilization of most of the macro and micronutrients. Heavy use of nitrogen (N) and phosphorus (P) fertilizers has become the major anthropogenic factors resulting in world-wide eutrophication problems in freshwater bodies and coastal ecosystems (Conley *et al.* 2009). In the perspective of sustainable agriculture, the application of modern nanotechnology in agriculture is considered asone of the important approaches to enhance crop production considerably and feed the world's fast growing population (Lal 2008). Important benefits of nanofertilizers over conventional chemical fertilizers rely on their (i) nutrient delivery system as they regulate the availability of nutrients in crops through slow/control release mechanisms. Such a slow delivery of nutrients is associated with the covering or cementing of nutrients with nanomaterials. By taking advantage of this slow nutrient delivery, farmers can increase their crop growth because of consistently long-term delivery of nutrients to plants. For example, nutrients can be released over 40–50 days in a slow release fashion rather than the 4–10 days by the conventional fertilizers, (ii) In addition, nanofertilizers are required in small amount which reduce the cost of transportation and field application, (iii) An additional major advantage is over accumulation of salt in soil can be minimized as it required in small amount, (iv) Another advantage for using nanofertilizers is that they can be synthesized according to the nutrient requirements of planned crops. In this regard, biosensors can be attached to a new innovative fertilizer that controls the delivery of the nutrients according to soil nutrient status, growth period of a crop or environmental conditions, (v) The miniature size, high specific surface area and high reactivity of nanofertilzers increase the bioavailability of nutrients and (vi) Providing balanced nutrition, nanofertilizers facilitate the crop plants to fight various biotic and abiotic stresses. It is reported in several crops that use of nanofertlizers and nanomaterials enhanced the growth and yield in several crops relative to plant treated with conventional fertilizers. Therefore, a paradigm shift from the traditional ways of crop production to technologies that could increase agricultural productivities with required nutrients, cost effective and efficient resource use that guarantees nutrient security, uplifts the value of production, boosts farmers' economy, delivers agri-value chain and supports pollution free environment is, therefore, the need of the day (Subramanian and Tarafdar 2011). The engineered nanoparticles (ENPs) are able to enter into plants cells and leaves, and can also transport DNA and chemicals into plant cells (Galbraith, 2007, Torney*et al.* 2007). The purpose of using nanomaterials (NMs) in the field of agriculture is to improve the efficiency and sustainability of agricultural practices by putting less input and generating less waste than conventional products and approaches.

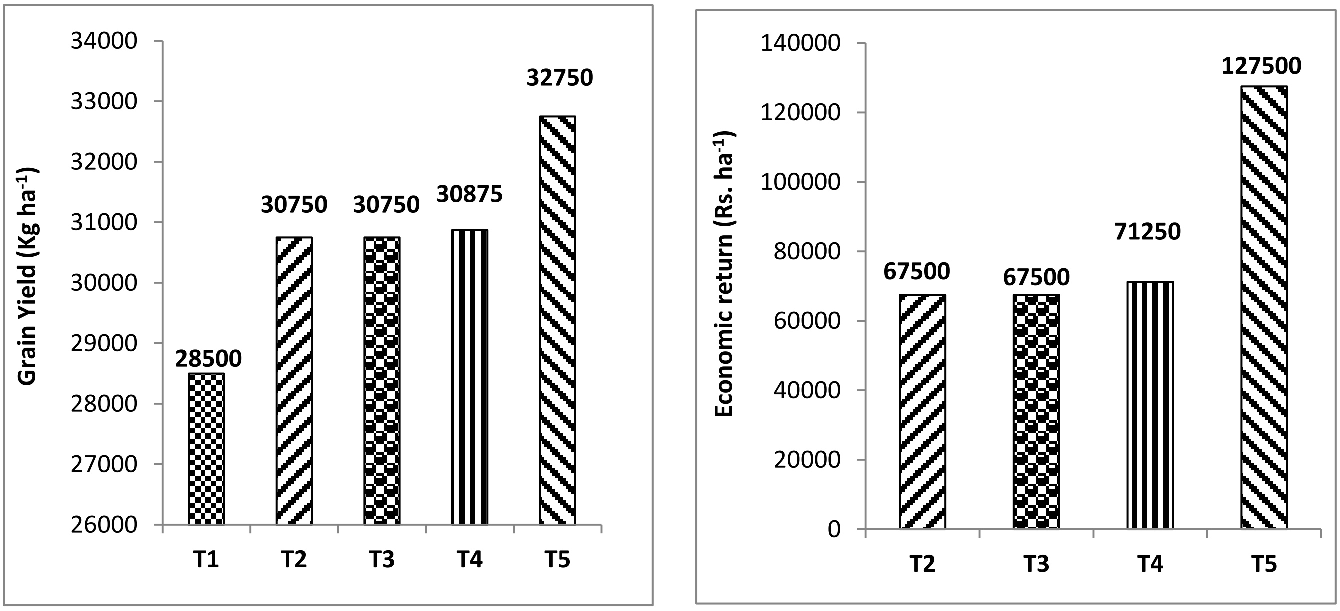


Fig. 8: Mean effect of IFFCO Nanofertilizers on the yield of Rose and economic returns (No. of trials – 4)

Plant fertilizers can be applied through the soil (for uptake by plant roots), through foliar spray (for uptake through leaves) (O'Neill *et al.* 2014) or both ways together (Yan *et al.* 2018). In this connection, carrier delivery systems of nanofertilizers can synchronize their release with their uptake by crops thus preventing undesirable loss of nutrients to soil (DeRosa*et al.* 2010). Some characteristics of nanoparticles, including the large specific surface area, unique magnetic/optical properties, electronic states, and catalytic re-activity confer nanoparticles a better reactivity than the equivalent bulk materials (Agrawal and Rathore, 2014). The actual application of delivery system for nanofertilizers came rather recently in agriculture (Roco 2011; Scott and Chen 2013). Nanofertilizers are aimed to make nutrients more available, consequently increasing nutrient use efficiency (Suppan, 2013). With nanofertilizer, there is slow release of the nutrients, which minimizes leaching of the nutrients among other interesting properties. The use of nanofertilizers is the most important application of nanotechnology in agriculture so far (Agrawal and Rathore, 2014). Regarding N fertilizers, the application of nanotechnology can provide fertilizers that release N when crops need it, eventually leading to increases in N efficiency through decreases in N leaching and emissions and long-term incorporation by soil microorganisms (Naderi and Danesh-Shahraki, 2013; Suman *et al.*, 2010).Nanofertilizers due to their characteristic features have great role in sustainable agriculture (El-Ramady 2014).Nanofertilizers or nano-encapsulated nutrients have properties effectively to release nutrients and chemical fertilizers on demand that regulate plant growth and enhance target activity (Nair *et al.* 2010). Nanoscale science and nanotechnology have the potential to transform the agriculture and food systems (Norman and Hongda 2013).

According to recent research works, nanofertilizers or nano-encapsulated nutrients have properties effectively to release nutrients and chemical fertilizers on demand that regulate plant growth and enhance target activity (Nair *et al.* 2010). Nanotechnology has the possibility to revolutionize agricultural systems (Manjunatha*et al.* 2016) enabling slow and controlled release of nutrient for the plants benefit, and ultimately increasing the amount of crop production with low environmental impact (Scott and Chen 2013). Nanotechnology seems to be the alternative that could revolutionize this field of agriculture which has the potential to increase food quality, global food production, plant protection, detection of plant and animal diseases, monitoring of plant growth and reduce waste for "sustainable amplification" (Prasad *et al.* 2014, Biswal*et al.* 2012, Ditta 2012, Sonkaria 2012). It has immense potentials in agricultural uprising, high reactivity, better bioavailability, bioactivity and the surface effects of NPs (Gutiérrez *et al.* 2011). Nanofertilizers or nano-encapsulated nutrients have properties effectively to release nutrients on demand that regulate plant growth and enhance target activity (Rosa *et al.* 2010, Nair *et al.* 2010). Urea modified hydroxyapatite nanoparticle-encapsulated *Gliricidiasepium*nanocomposite exhibited a slow and sustained release of nitrogen over time at 3 different pH values (Kottegoda et al, 2011). Manikandan and Subramanian (2014) reported that nanoporous zeolite used on N fertilizer might be used as alternate strategy to enhance the effectiveness of N used in crop production system. Soil amended with metallic Cu NPs significantly increased 15 day lettuce seedling growth by 40% and 91%, respectively (Shah and Belozerova 2009). Some studies focused on the characteristics of NPs also revealed that NPs can enter plant cells and transport DNA and chemicals inside the cell (Ambrogio*et al.* 2013, Ghafariyan*et al.* 2013, Torney*et al.* 2007). These studies provide a platform on which we can assume that NPs can also deliver nutrients to the plants as fertilizers. Moreover, nanofertilezers have great impact on the soil as nanofertilizers can reduce the toxicity of the soil and decrease the frequency of fertilizer application (Naderi and Danesh-Shahraki 2013). DeRosa*et al.* (2010) reported that in nanofertilizers, nutrients can be encapsulated by NMs, coated with a thin protective film or delivered as emulsions or NPs. Nano and subnano composites control the release of nutrients from the fertilizer capsule (Liu *et al.* 2006). Nanoscale science and nanotechnology have the potential to transform the agriculture and food systems (Norman and Hongda, 2013). In previous studies, urea-loaded zeolite chips (Millan *et al.*, 2008) and nanocomposites containing N (Jinghua, 2004) have been used to induce a slow N release and increase plant N uptake. Other materials being used for the same purpose include nutrient sources coated with thin polymer films and nutrients encapsulated inside nanoporous materials (Rai *et al.*, 2012).

In conclusion, nanotechnologydesigning ultra-small particles is now emerging as a promising way to promote plant growth and development. Nanofertilisers are expected to conserve natural mineral reserves and energy (as making fertilizer is very energy-intensive), enhance nutrient use efficiency, reduce water contamination and protect environment arresting nutrient losses and enhance crop yields. It also can enhance plants' nutritional values. Most of the researches conducted at global level on nanofertilizerssuggest that these materials could help solve the world's most pressing resource problems at the food-energy-water nexus. Apparently, nanotechnology have greater role in crop production with environmental safety, ecological sustainability and economic stability.

ACKNOWLEDGEMENT

We are highly grateful to Dr. U. S. Awasthi, Managing Director, IFFCO for his keen interest, constant supervision, wholehearted support and praiseworthy guidance to initiate and successfully complete this investigation. We sincerely extend our thanks to IFFCO Field Officers for religiously conducting these on farm trials and collecting data successfully, especially during COVID-19 lock-down period safely observing full precaution.

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